



Original communication

Histopathological detection of entry and exit holes in human skin wounds caused by firearms

Marcus Vinícius Baptista^{a,b,*}, Solange C.G.P. d'Ávila^b, Antônio Miguel M.P. d'Ávila^c^a Medical Legal Institute, São José do Rio Preto, SP, Brazil^b Department of Pathology and Forensic Medicine, Faculty of Medicine of São José do Rio Preto, SP, Brazil^c Medical Legal Institute, Ribeirão Preto, SP, Brazil

ARTICLE INFO

Article history:

Received 20 January 2014

Received in revised form

5 March 2014

Accepted 16 April 2014

Available online 28 April 2014

Keywords:

Gunshot wounds

Human skin

Histopathology

ABSTRACT

The judiciary needs forensic medicine to determine the difference between an entry hole and an exit hole in human skin caused by firearms for civilian use. This important information would be most useful if a practical and accurate method could be done with low-cost and minimal technological resources. Both macroscopic and microscopic analyses were performed on skin lesions caused by firearm projectiles, to establish histological features of 14 entry holes and 14 exit holes. Microscopically, in the abrasion area macroscopically observed, there were signs of burns (sub-epidermal cracks and keratinocyte necrosis) in the entrance holes in all cases. These signs were not found in three exit holes which showed an abrasion collar, nor in other exit holes. Some other microscopic features not found in every case were limited either to entry holes, such as cotton fibres, grease deposits, or tattooing in the dermis, or to exit holes, such as adipose tissue, bone or muscle tissue in the dermis. Coagulative necrosis of keratinocytes and sub-epidermal cracks are characteristic of entry holes. Despite the small sample size, it can be safely inferred that this is an important microscopic finding, among others less consistently found, to define an entry hole in questionable cases.

© 2014 Elsevier Ltd and Faculty of Forensic and Legal Medicine. All rights reserved.

1. Introduction

In South America, where 74% of homicides are hired by firearms, Brazil is in 3rd place, behind only Venezuela and Colombia. The most affected age group is between 20 and 29 years old.^{1,2} About 50,000 deaths per year in Brazil are due homicide.²

Currently, the homicide rate in Brazil is 29.6 per 100,000 inhabitants and the use of a firearm in the period 1980–2010 had increased by approximately 346%.²

Victims of externally caused injuries are of interest to both medical and legal authorities, as the former focus on treatment, and the latter on public and social needs. Legal authorities seek from forensic medicine extrajudicial knowledge to assist in the defence of rights and interests of human beings and society. Grandmaison et al., in 2008 concluded that the determination of manner of death

in case of gunshot wounds may be difficult in routine forensic practice, especially to decide between homicide and suicide.³

Human skin has three layers of tissue: superficial (epidermis), middle (dermis) and deep (hypodermis or subcutaneous tissue).⁴ Alterations in the skin produced by firearm projectiles may indicate the direction of the shot, an extremely important piece of information for the legal authorities, although this is not always easy to determine.⁵

The moment the skin is reached by a projectile discharged from a weapon, lesions are caused by direct impact. The epidermis is the first layer to suffer an injury and the diameter of the entry hole is in most cases smaller than the calibre of the damaging bullet.^{5,6} In entrance wounds, the edges are generally inverted, as the trauma occurs from outside the elastic skin surface. Around the entry hole there is an area called the ecchymotic ring, which is formed by haemorrhage in the dermis from rupture of blood vessels surrounding the wound. This purple-coloured rim is not exclusive to entry holes and may also occur around exit holes. Around the entry hole, but also occasionally observed in exit wounds, is an abrasion collar, which can be called a ring or area of contusion.

When discharging a firearm, combustion of gunpowder occurs extremely fast in a more or less complete manner inside the

* Corresponding author. Rua Celso Spínola de Castro, 460, São José do Rio Preto, SP CEP 15.090-200, Brazil.

E-mail addresses: ortopedia@terra.com.br, helioisacaldas@hotmail.com (M. V. Baptista).

weapon, leaving residues of unburned gunpowder with other materials inside the barrel, i.e. gunshot residues. They adhere to the projectile, are propelled out of the barrel of the weapon, hit the skin and dirty the entry hole. They are also called bullet wipe, a dark zone which lies inside the abrasion collar, which is unique to the entry hole.⁷

These three skin alterations produced by the impact of the projectile from a firearm and visible to the naked eye, ecchymotic ring, abrasion collar, and bullet wipe, are considered primary effects.

Secondary effects of firearm wounds are related to gases and residues arising from the combustion of gunpowder. They can only be identified in contact or close range gunshots, but cannot always be found in such cases. If there is an obstacle separating the shooting weapon and the victim, these elements of macroscopic diagnosis may be absent in the skin. There are three secondary effects: 1) charring, scorching or burn area, 2) soot soiling or smoke fouling and 3) tattooing.

The scorching or burn area is produced by the action of super-heated and inflamed gases leaving the barrel at discharge. The distance between the firearm and the target produces burning and structural modifications according to the temperature of the gases. Scorching causes a relatively violent dissection of tissues, with the formation of fissures between layers of skin, splitting the epidermis from the dermis and breaking down into their constituent elements.⁶ Soot soiling is produced by deposits of soot after the combustion of gunpowder around the entry hole, which is easily removed. It is clearly observed macroscopically when black powder is used, but is less intense when smokeless chemical powder is employed. Tattooing is produced by grains of gunpowder, burned or not, which are projected at discharge. The grains encrust the entire entry hole, and cannot be removed by washing or cleaning the surface. They look like dark dots. Tattooing is typical of entry holes.

Exit holes are produced by projectiles, alone or combined with elements which were carried during their trajectory through the body (clothes, buttons, bones, teeth, cartilage, organ fragments, and muscles). They usually show everted, bleeding and irregular edges, and are usually larger in diameter than entry holes. They do not show bullet wipes or any secondary features. Ecchymotic rings may be observed around the lesion. An abrasion collar may be present if the projectile, when leaving the body, finds resistance in the tissues. Histopathologically, there is a greater infiltration of fat in exit wounds.⁸ Although there are well-defined macroscopic features to differentiate an entry hole from an exit hole, it is not always possible to establish a difference based on macroscopic findings alone. We investigated whether histopathological study of skin lesions could be used to determine an entry hole and an exit hole more accurately.

2. Methods

This study was approved by the Research Ethics Committee of the Department of Pathology and Forensic Medicine of the Faculty of Medicine of São José do Rio Preto (no. 166/2003) and the Board of the Institute of Forensic Medicine of the State of São Paulo. We selected four victims killed by injuries caused by firearm projectiles for civilian use. A total of 14 entry holes and their respective 14 exit holes were macroscopically identified and photographed. For the macroscopic identification of entry holes both primary and secondary effects were investigated. Each lesion was removed with a scalpel blade, using the technique of conization starting from the centre of the wound with approximately 3 cm radius and 1 cm depth. The material was fixed in 20% formaldehyde, submitted to routine histological processing, embedded in paraffin, sectioned at 5 µm, stained with haematoxylin and eosin (HE), and examined microscopically.

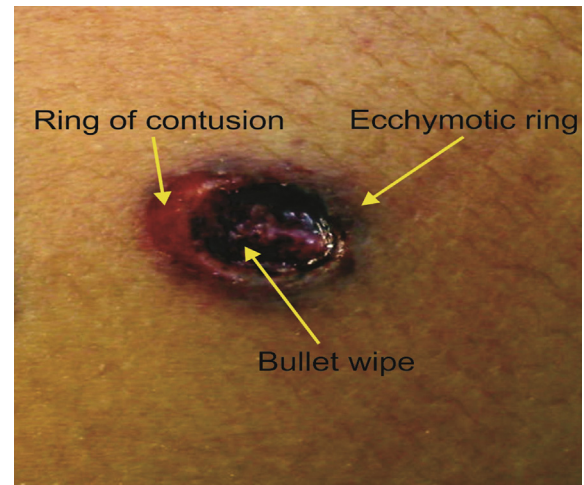


Fig. 1. Primary effects in an entry wound in skin caused by a firearm projectile.

3. Results

Macroscopic analysis of the entry holes showed abrasion collars and ecchymotic rings in all 14 cases. The bullet wipe and inverted edges were observed in 12 cases (Fig. 1). Everted edges, typical of exit holes, were found in two entrance wounds. A scorching area, soot soiling and tattooing were not observed macroscopically in any of the entry wounds. Macroscopic analysis of the exit holes showed everted edges in 13 cases, but no inverted edges. Abrasion collars and ecchymotic rings were observed in three cases. Bullet wipes, scorching, soot soiling and tattooing were not observed.

Microscopic analysis of the entry holes showed foreign bodies in the epidermis in four cases, and in the dermis in eight cases. These were cotton fibres and grease deposits, and corresponded to the bullet wipe. Burns in the epidermis showing keratinocyte necrosis, and haemorrhage, coagulative necrosis and subepidermal cracks in the dermis were observed in all 14 cases (Fig. 2). Tattooing in the dermis was seen in three cases. No adipose tissue was seen in any case in the epidermis or dermis (Table 1).

Microscopic analysis of the exit holes showed adipose tissue in the epidermis in one case, and other tissues in the epidermis in two cases. No case of keratinocyte necrosis due to burns in the

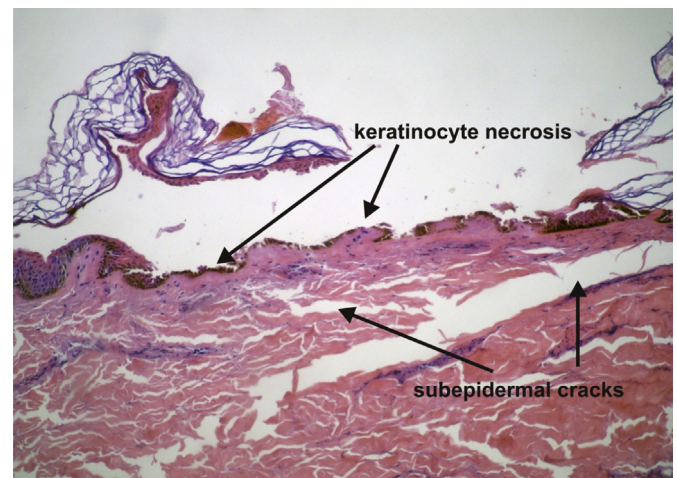


Fig. 2. Histological section of an entry wound in skin. Note keratinocyte necrosis and subepidermal cracks. HE ×100.

Table 1

Comparison table between the findings in injuries of entry and exit.

	Entry holes		Exit holes		p
	N	%	N	%	
Foreign bodies in the epidermis	4	28.6	2	14.3	0.6
Adipose tissue in the epidermis	0	0	1	7.2	1
Burns in the epidermis	14	100	0	0	0.001
Coagulative necrosis in the dermis	14	100	12	85.7	0.48
Foreign bodies in the dermis (cotton fibres and grease deposits)	8	57.2	0	0	0.0019
Foreign bodies in the dermis (bone and muscle tissue)	0	0	6	42.8	0.00159
Adipose tissue in the dermis	0	0	7	50	0.0058
Haemorrhage in the dermis	14	100	10	71.5	0.09
Tattooing in the dermis	3	21.5	0	0	0.22

epidermis was observed (Fig. 3). In the dermis, coagulative necrosis was observed in 12 cases, haemorrhage in ten, adipose tissue in seven, and bone and muscle tissue in six. No cotton fibres, grease deposits or tattooing were observed under the microscope in any exit hole (Table 1).

4. Discussion

In some cases, there may be a divergence of opinion about whether or not a gunshot wound is an entry or exit hole. It is a problem faced by forensic pathologists on a daily basis.⁷ Such divergence may have serious legal ramifications, which would hinder law enforcement. It could prejudice people's rights and possibly condemn an innocent person or lead to acquittal of a murderer.

For a better macroscopic assessment of a wound, it is necessary that the signs visible to the naked eye have not been altered by handling, decomposition of the body or other factors. The victim is often alive when brought to a medical facility where urgent care is provided. During this procedure, clothes are removed and the skin lesions caused by firearm projectiles are treated. If a victim dies, the corpse is submitted without clothes to forensic medicine institutes and the original macroscopic characteristics of the skin lesions are modified, which renders a more reliable diagnosis difficult.⁹

It is commonly asserted that the edges of the exit hole are everted, whereas the edges of the entry hole are inverted. Our study

largely confirmed this assertion, as everted edges were found in 13 out of 14 exit holes, although in one of the exit holes this was not found, which demonstrate that questionable cases may occur. Thoinot stated that typical patterns which macroscopically differentiate an entry hole from an exit hole will not always be found, and also that a larger number of exit holes than entry holes may be found, explained by fragmentation of the projectile during impact against bones.¹⁰ Other causes for more than one exit wound but only one entry wound are that pieces of bone may be expelled from the body by the projectile, or even that two projectiles may penetrate the same hole, change their path inside the body, and cause different exit wounds. A single projectile generally produces just one entry hole, but may produce more than one.

There is a consensus about the difficulty in distinguishing an entry wound from an exit wound when a projectile perforates soft parts only or a small segment of the body, or if the wounds are close to each other. In the case of gunshot contact wounds, the entry wounds may be larger and irregular, and they may be confused with exit wounds, which, in these cases, can be smaller and yet usually irregular in outline. In case of doubt concerning which wound is the entry or the exit wound, additional examinations should be conducted to assist in the diagnosis, including histopathological tests.

Because histopathology is an easily accessible additional examination. Such examination is not always used and little reference to its details can be found in the medical literature. Microscopically, the abrasion collar described macroscopically showed signs of burns in the entry holes in all cases.¹¹

This sign was not found in the three exit holes which showed an abrasion collar. Although the number of samples was not high, our findings showed that microscopic signs of burns are an important feature to determine an entry hole in questionable cases. Cotton fibres and grease deposits observed under the microscope in eight entry holes and the absence of such materials in exit holes showed that these microscopic findings, when present, are characteristics of an entry hole. Microscopic analysis of the dermis of the exit holes showed adipose tissue in seven holes and muscle fibres and bone tissue in six. The presence of these materials in the dermis provides indication of an exit hole.

Unlike the traditional methodology commonly used by forensic pathologists to determine entry and exit holes, which in most cases involves a simple macroscopic and subjective analysis, this work indicates objective features grounded in diagnostic histopathology.

5. Conclusions

The microscopic findings of coagulative necrosis of keratinocytes associated with subepidermal crack and tattooing are characteristic of entry holes, whereas the presence of adipose, muscular and bone tissue in the dermis is characteristic of exit holes.

Therefore the results demonstrate that histological analysis of skin wounds caused by firearm projectiles provide input for a more accurate diagnosis of entry and exit holes.

Ethical approval

The study was submitted to the Ethics Committee and research under the number 5326/2003, on the day 6 of November of 2003 and it was approved by Faculdade de Medicina de São José do Rio Preto, São Paulo, Brazil.

Funding

None.

Conflict of interest

There is no competing interests.

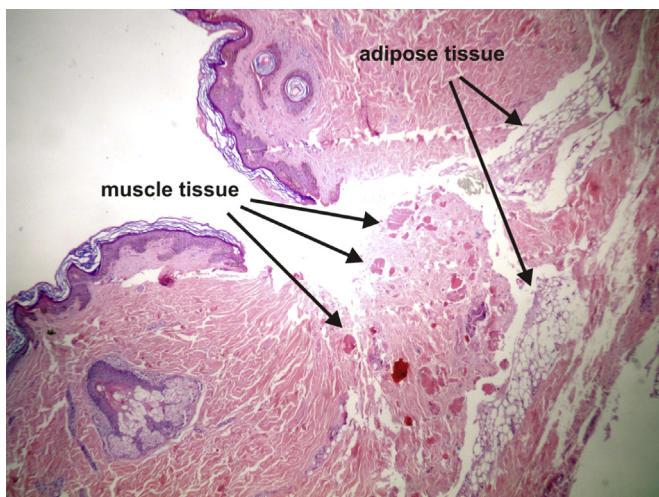


Fig. 3. Histological section of an exit wound in skin. There are no keratinocyte necrosis or subepidermal cracks, but adipose and muscle tissue are seen in the dermis. HE $\times 40$.

References

1. United Nations Office on Drugs and Crime (UNODC). *Global study on homicide – trends, contexts, data*; 2011. Vienna.
2. Murray J, Cerqueira DR, Kahn T. Crime and violence in Brazil: systematic review of time trends, prevalence rates and risk factors. *Aggress Violent Behav* 2013;**18**: 471–83.
3. de la Grandmaison GL, Fermanian C, Aegerter P, Durigon M. Influence of ballistic and autopsy parameters on the manner of death in case of long firearms fatalities. *Forensic Sci Int* 2008;**177**:207–13.
4. Cornelison RL, Crowson AN. Cutaneous reactions to exogenous agents. In: Barnhill RL, editor. *Textbook of dermatopathology*. 2nd ed. New York: McGraw-Hill Professional; 2004. pp. 3–6.
5. Druid H. Site of entrance wound and direction of bullet path in firearm fatalities as indicators of homicide versus suicide. *Forensic Sci Int* 1997;**88**:147–62.
6. Carvalho HV. Exames complementares. In: Carvalho HV, editor. *Manual de técnica tanatológica*. São Paulo: Rosselello; 1950. pp. 122–58.
7. Desinan L, Mazzolo GM. Gunshot fatalities: suicide, homicide or accident? A series of 48 cases. *Forensic Sci Int* 2005;**147**(Suppl.):S37–40.
8. Stone IC, DiMaio VJ, Petty CS. Gunshot wounds: visual and analytical procedures. *J Forensic Sci* 1978;**23**:361–7.
9. Nikolić S, Zivković V, Babić D, Juković F. Suicidal single gunshot injury to the head/differences in site of entrance wound and direction of the bullet path between right – and left – handed – an autopsy study. *Am J Forensic Med Pathol* 2012;**33**:43–6.
10. Thoinot LH. *Précis de médecine légale*. Paris: Doin; 1913.
11. Cornelison RL, Crowson AN. Cutaneous reactions to exogenous agents. In: Barnhill RL, editor. *Textbook of dermatopathology*. 2nd ed. New York: McGraw-Hill Professional; 2004. pp. 318–30.